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JOINT MEASUREMENTS OF WIND AND TEMPERATURE STRUCTURE IN THE WINTER MESOSPHERE AT HIGH LATITUDES

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ABSTRACT

An attempt to identify propagating internal gravity waves in the mesosphere was made by sounding the region with three instrumented rockets on January 13-14, 1970, from Churchill, Canada (59°N). The three observations, which were conducted at approximately 90 min. intervals, consisted of a pitot probe bracketed by two acoustic grenade soundings. Thus, two temperature and wind profiles and one density profile were obtained independently, permitting an examination of the thermodynamic structure and the wind structure. The results of the combined thermodynamic and wind observations were found to be quantitatively compatible with a gravity wave interpretation. This interpretation also predicts vertical velocities on the order of 10 msec^{-1} in the 80 km region.

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INTRODUCTION

It has been shown by Eberstein (1969), among others, that in the mesosphere, the deviations of temperature from the vertical mean profile at high latitudes in winter, coupled with the associated deviations of density and pressure, may be explained by internal gravity wave theory. However, it is also possible that latent heat releases in the troposphere can generate wave-like features in the temperature structure of the mesosphere (Eberstein and Theon, 1971; Eberstein and Shere, 1971) which have an appearance similar to that caused by gravity waves. Furthermore, these features persist for a relatively long time, and may thus be advected from their source of generation, such as a storm, to the point where they are observed. Consequently, a suitable thermodynamic structure alone is not strictly adequate to establish that the observed wave-like features are due to gravity waves.

The disturbed thermodynamic structure caused by gravity waves is associated with a corresponding characteristic wind pattern. Thus joint observations of thermodynamic deviations and wind should aid in confirming or refuting the presence of gravity waves.

EXPERIMENT

An attempt to identify propagating internal gravity waves in the mesosphere was made by sounding the region with three instrumented rockets during a 192 minute period on January 13-14, 1971, from Churchill, Canada (59°N). The first sounding was conducted at 2223 GMT with the acoustic grenade technique to

measure the temperature and wind profiles in the 35-90 km region; the second sounding was launched 88 minutes later (2351 GMT) and employed a pitot probe to measure the density profile with 0.5 km vertical resolution; and the last sounding again was made with the acoustic gennade technique 104 minutes after the pitot sounding (0135 GMT). Thus, two temperature and wind profiles, and one density profile were obtained independently to permit an examination of the thermodynamic structure, the wind structure, and the interdependence of each in the mesosphere. For descriptions of the experimental techniques, see Smith, et al (1968).

ANALYSIS OF DATA

An average atmosphere was calculated based on the three soundings, and the differences of the pitot data from the mean were computed (these are referred to as perturbations). The observed perturbations are shown as the solid curves in figures 1 and 2, and are seen to give a pattern characteristic of internal gravity waves in a stratified, compressible fluid. Such findings have been previously discussed by Eberstein (1969, 1971), who concluded that knowledge of the wind behavior associated with the thermodynamic perturbations is important in identifying gravity waves. A thermally damped gravity wave was calculated to match the experimental deviations of temperature as shown by the broken curve in figure 1. The corresponding deviations of pressure and density are shown by the broken curves in figure 2, where the solid curves correspond to the experimentally observed deviations. The matching of experimental thermodynamic data with thermally damped gravity waves is discussed elsewhere (Eberstein, 1969, 1971), and will not be repeated here. The associated theoretical wave

parameters include a wave period of 20 minutes and a horizontal wave length of 60 km. The mean experimental (N-S) wind was essentially zero until about 60 km, then increased with altitude, the direction being from north to south. For the calculation, the background wind (in the N-S direction) was taken to be zero between 30 km and 60 km; then increasing to 12 msec^{-1} at 96 km. This wind was put into the gravity wave calculation as positive, suggesting that the observed wave propagates from north to south.

Figure 3 shows the comparison between the zonal wind profile measured by the first grenade sounding, and the wind pattern associated with the theoretically calculated gravity wave. (A zonal drift wind varying linearly from 12 msec^{-1} at 36 km to 44 msec^{-1} at 96 km has been included). The wind pattern obtained by the second grenade sounding is similar. Figure 4 shows the theoretical vertical velocity profile, which includes values of approximately 10 msec^{-1} in the 80 km region. Justus and Edwards (1971) have reported measured vertical velocities on the order of 20 msec^{-1} at altitudes between 88-118 km. These measurements were at a different latitude and time of year, and are therefore not directly comparable. However, the Justus and Edwards data do confirm the existence of relatively large vertical velocities at high altitudes.

The vertical velocity profile given by figure 4 was included in the data reduction for the two grenade soundings and the effect on the mean profile was found to be negligible.

CONCLUSIONS

The results of an initial experiment to study winds and thermodynamic variations jointly suggest a gravity wave interpretation to explain the behavior of the

upper atmosphere in this case. Structure resembling that described here is quite common in the winter at high latitudes. However, it is recognized that more extensive and detailed experiments will be needed to rigorously identify gravity waves. Additional simultaneous measurements of winds and thermodynamic variations would be especially valuable in this regard.

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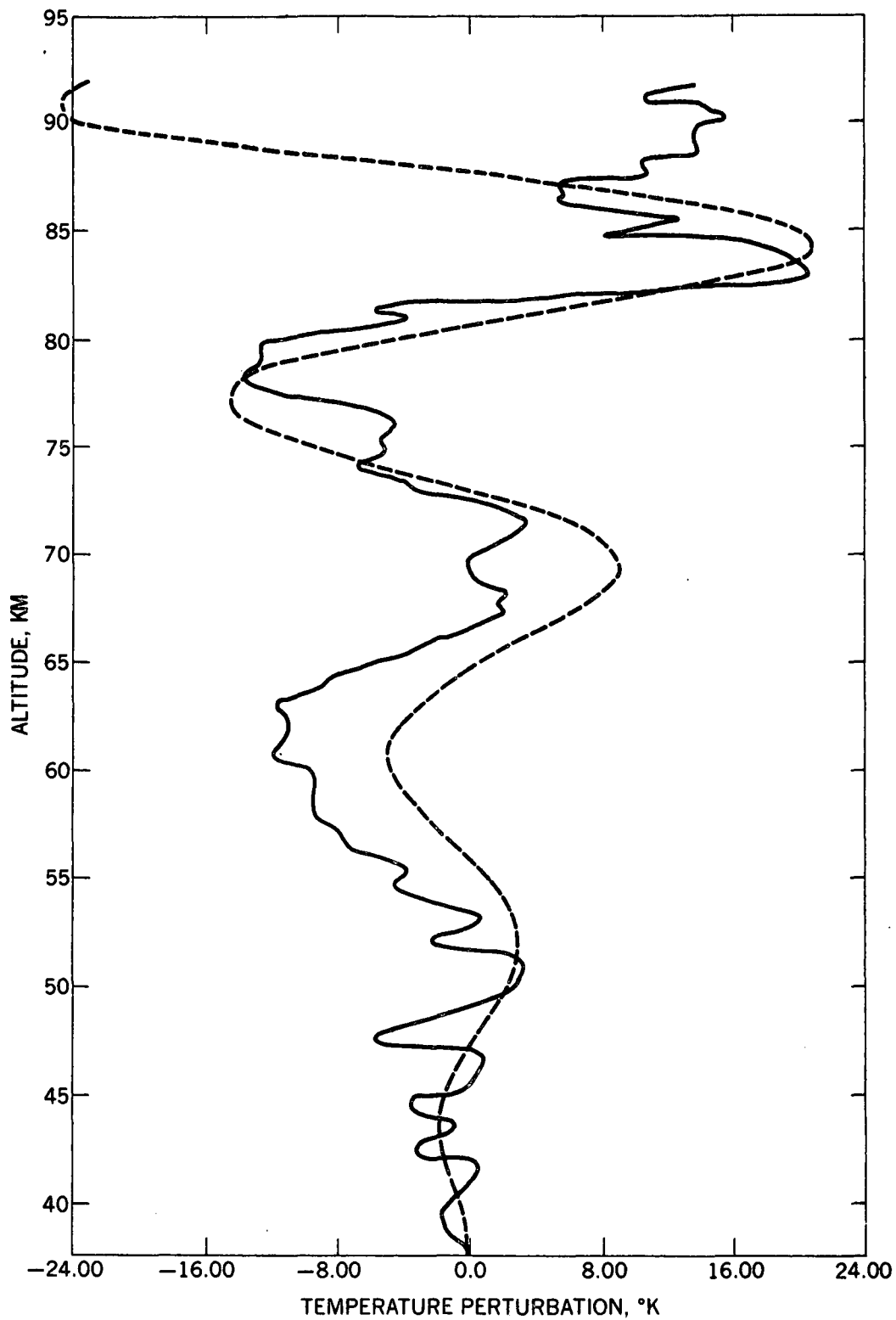


Figure 1. The observed temperature perturbations (solid curve) compared with the perturbations calculated from theory (broken curve) as a function of altitude for the described experiment.

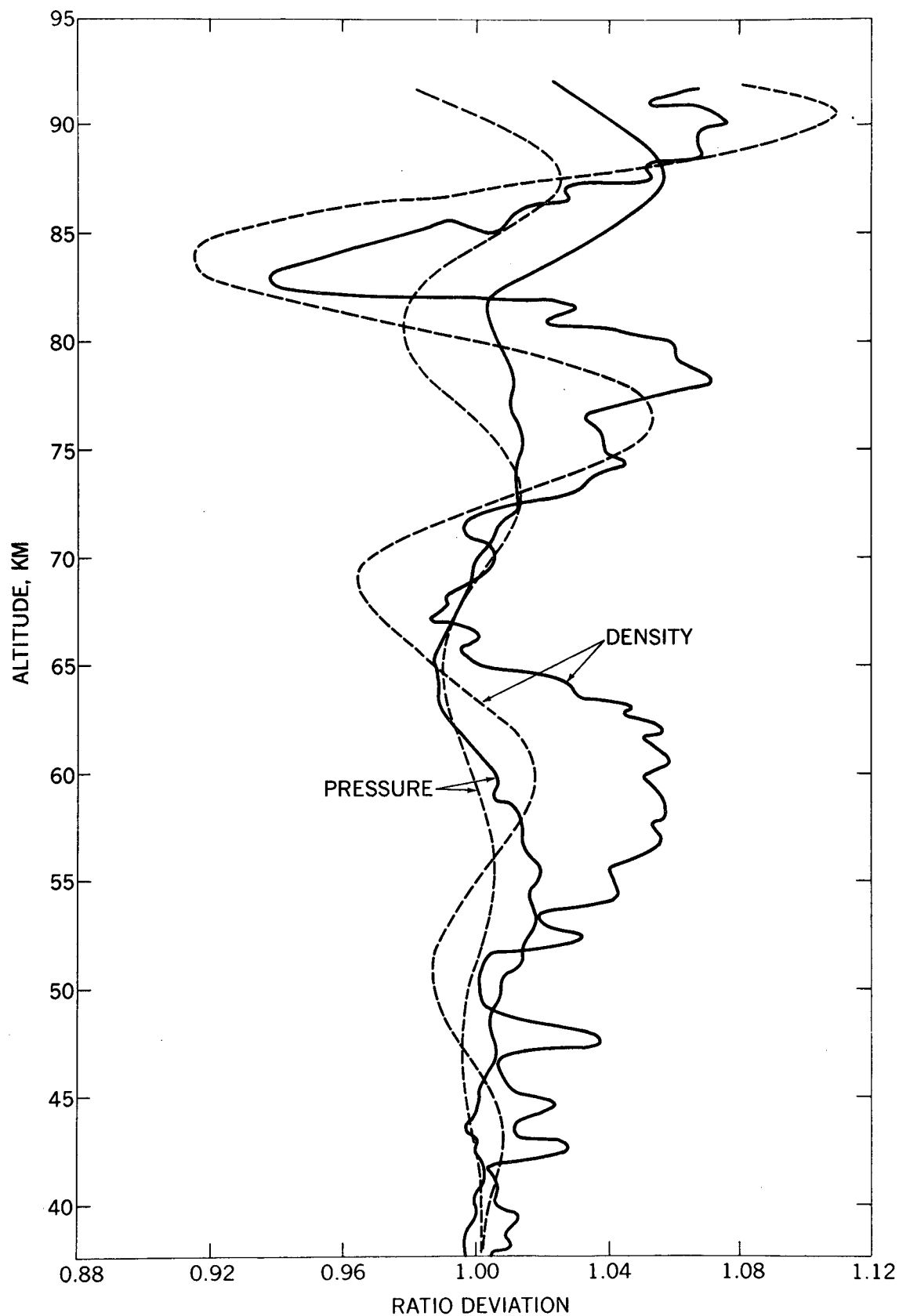


Figure 2. The observed pressure and density perturbations (solid curves) over Churchill on January 13-14, 1970 compared with the perturbations calculated from theory (broken curves) as a function of altitude.

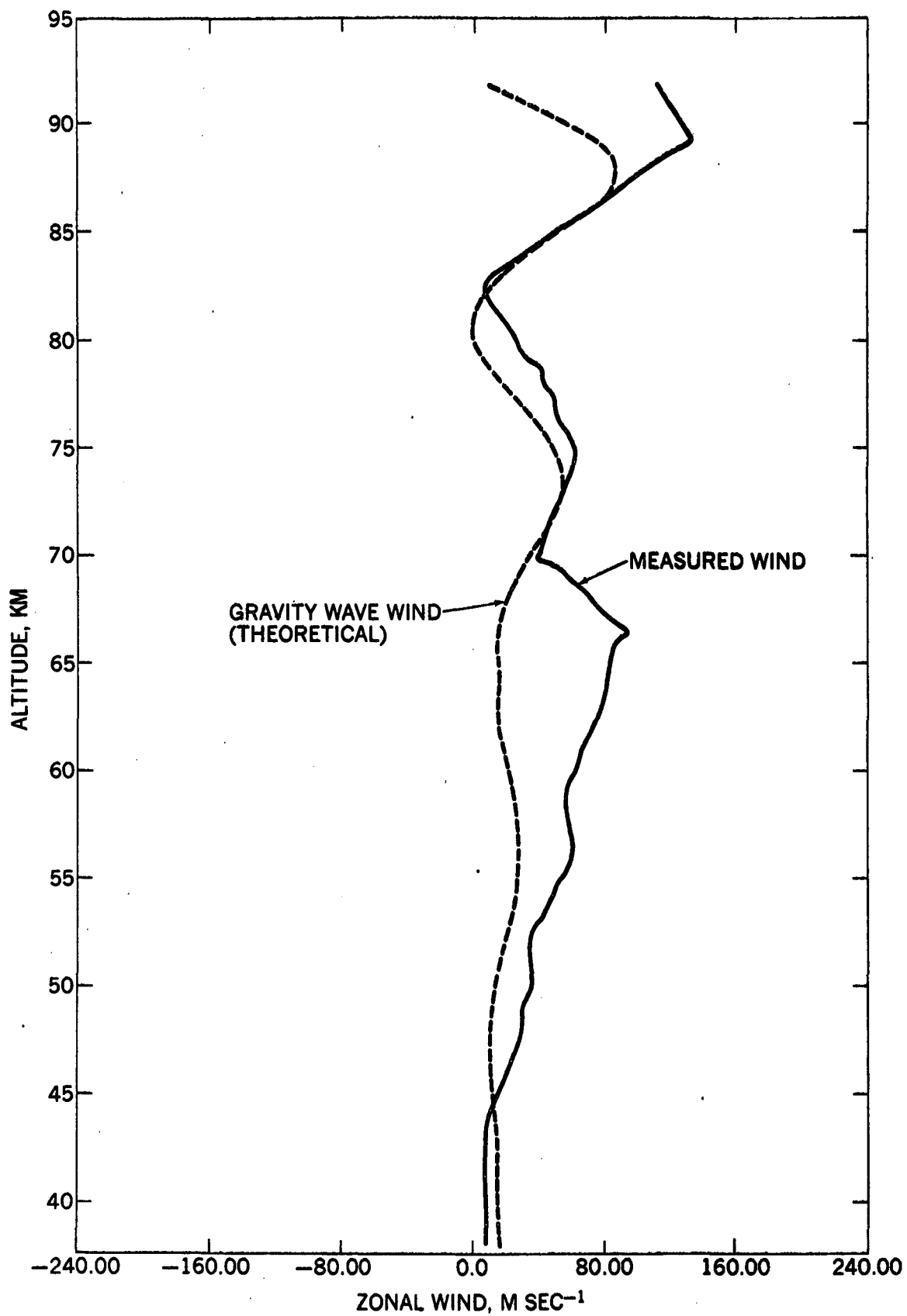


Figure 3. The observed zonal wind component compared with the zonal wind profile calculated from the theory for the described experiment.

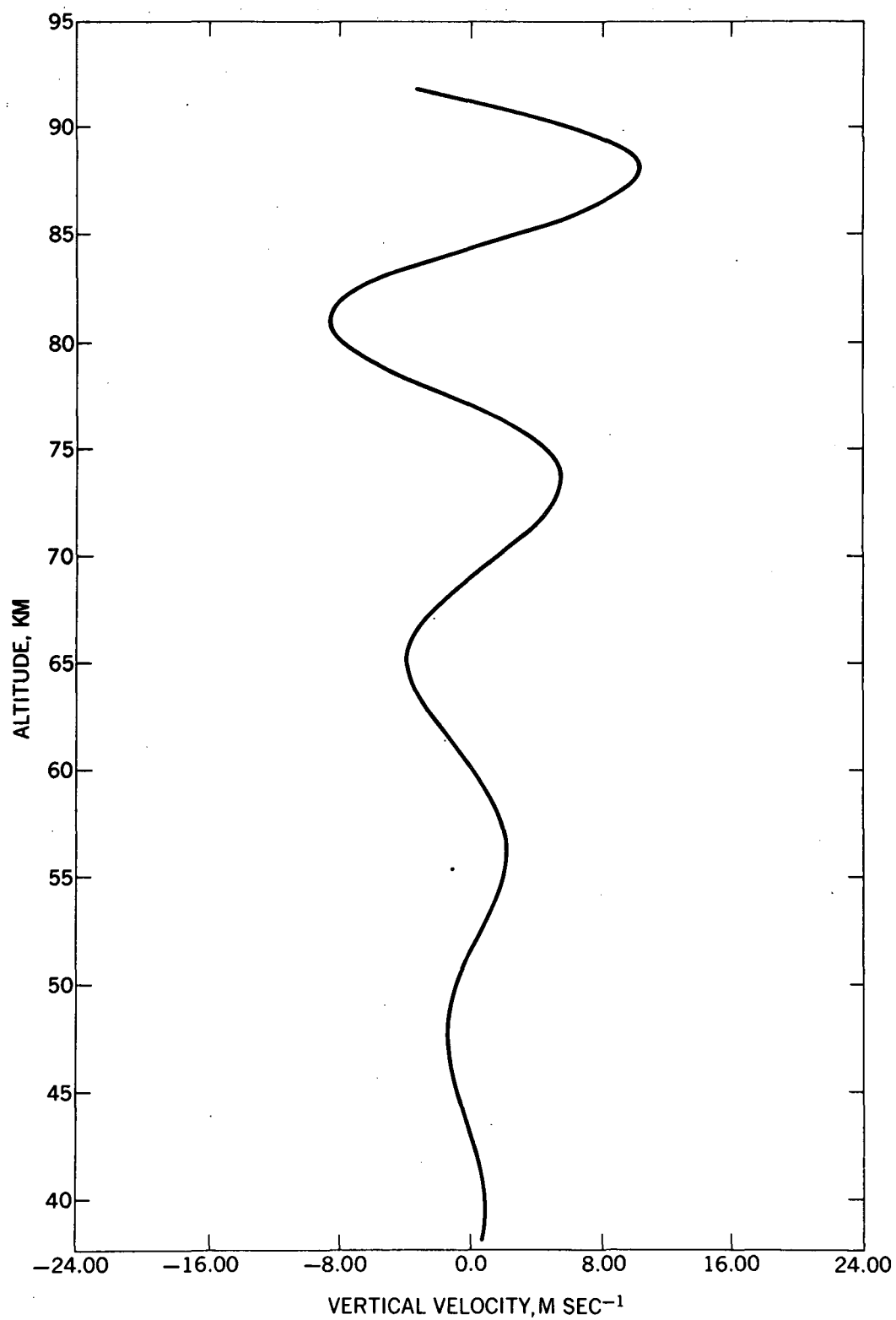


Figure 4. The theoretical vertical velocity profile which is consistent with the gravity wave given by figures 1-3.